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Diversity and Abundance Survey of Bat Species in Amurum Forest Reserve North-Central Nigeria

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Abstract- Diversity and abundance of bats were determined in four habitat types in and around Amurum Reserve, Nigeria between May and June, 2014. Two representative sites for bat surveys were selected from each of the four habitat types in the reserve and one from the surrounding area: (i) gallery forest, (ii) savannah, (iii) rocky outcrop, and (iv) farmland. Bats were trapped at four stations in each habitat type. Bat species diversity and abundance were estimated by capturing. Three hundred and twenty-one bats representing at least nine species of seven genera in two families were recorded across the four habitat types. The species recorded included: *Eidolon helvum, Epomophorus anurus, Epomophorus gambianus, Epomophorus wahlbergi, Micropteropus pusillus, Myonycteris* species, *Nanonycteris veldkampi, Rhinolophus* species, and *Rousettus aegyptiacus.* Species diversity was highest in the savannah habitat, followed by farmland, rocky outcrop and gallery forest. Species richness was highest in savannah, followed by farmland, gallery forest and rocky outcrop. Pielou's index revealed even distribution of abundance amongst bat species in the farmland, followed by rocky outcrop and savannah on equal scale relative to the gallery forest. Jaccard index (SCj) for comparing species richness between habitat pairs indicated the highest level of similarity between gallery forest and savannah habitat. Of all the bat species captured, *M. pusillus* was the most abundant. The gallery forest has the potential to host a great degree of bat species relative to other habitat types due to its associated higher structural complexity, which hosts a variety of resources required by bat species. The savannah and rocky outcrop habitat types also play significant complementary role in improving bat species assemblages in Amurum Forest Reserve. Low bat species abundance recorded in the farmland is an indication of high levels of habitat simplification and disturbance through various agricultural practices. To improve this, farmland practices should enhance landscape complexity, favour structural variation and connectivity, and make effort to minimize the spread of pesticides, as these pose serious threats to bat populations. This can be achieved by planting trees indigenous to the plateau at different heights.

Keywords- *diversity, abundance, Amurum Reserve, bat capture*

I. INTRODUCTION

Bat species diversity and abundance have declined worldwide. The role of bats as bio-indicators and immense contribution to our biodiversity makes this a great concern. Of about 5000 species of mammals globally, bats represent approximately 20% of all classified species worldwide, with about 1,240 bat species [1]. Bats are mammals of the order Chiroptera whose forelimbs form webbed wings, making them the only mammals naturally capable of true and sustained flight. Studying bats in the wild is difficult due to their elusive nature; they fly beyond our reach and make sounds we cannot hear. The small size and cryptic appearance of some species necessitates capture for identification.

Habitat availability is a major determinant of the diversity and abundance of many taxa, including bats. Measurements of the species richness and abundance of birds, bats, butterflies, and dung beetles in riparian forest and secondary forest, forest fallows, live fences, and pastures with high and low tree cover, showed significant differences in mean abundance and species richness of birds and bats but none in dung beetles or butterflies; with species richness of bats and birds being positively correlated with tree species richness [2]. Forest type [3] and landscape composition [4] have been identified as a tool in determining abundance of bat species. Microchiropteran bats have also been identified to have the potential of being an important biodiversity indicator species on the basis of their global distribution and important ecosystem functioning [5].

To effectively conserve bats we need to understand their habitat associations. Although we already know a lot about general bat-habitat associations, we don't know enough about this in some parts of the word (e.g. Africa) and to effectively halt bat diversity loss we need to know more about this. The fact that bats provide an essential ecosystem service through top-down control of herbivorous insects, makes their presence and activity an effective strategy to assure vital ecosystem functioning in production forest systems. Bats have been recognized to play key ecological roles as seed dispersers, pollinators and predators of insects and small vertebrates [6, 7].

References [8] and [9] recognized the importance of developing sustainable conservation and management within modified forest landscapes through understanding the effects of vegetation structure in differently managed forests on patterns of species richness and relative abundance of animals. In the effort to effectively conserve bats, there is the need to understand how species respond to different habitat types and which structural characteristics affect habitat use. Biodiversity conservation has been recognized not to depend only on the maintenance of protected forest areas, but also on the scope for conservation within the agricultural matrix in which they embedded [2]. Conservation of remaining forest fragments coupled with encouraging farmers to maintain tree cover in pastures and along boundaries has been identified to make an important contribution to animal conservation [2].

Compared to other parts of the world, African bat species are less studied and Jos provides a multi-habitat landscape which is expected to accommodate a great diversity of bat species. This information can be useful in exploring how bats use different habitat types.

The aim of this research project was to assess bat species diversity and abundance in Amurum Reserve, Nigeria. The objectives of this study were to determine bat species diversity and abundance and test the effect of habitat types on bat species richness and abundance in Amurum Reserve.

We hypothesized that bat species diversity and abundance would differ among the different habitat types and we predicted that species diversity and abundance would increase with habitat structural complexity (from least structured habitat in the rocky outcrop, to savannah and gallery forest).

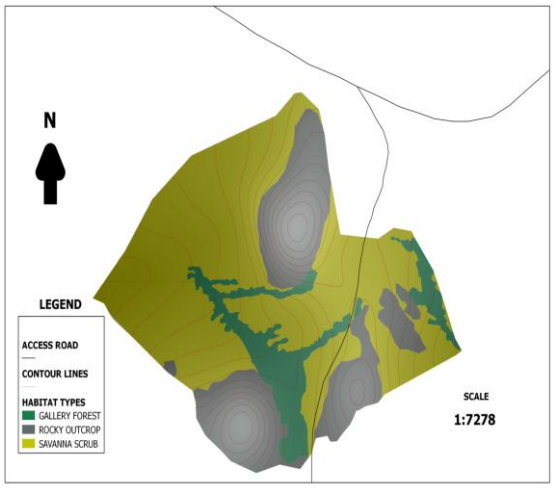

Figure 1. Map of Amurum Forest Reserve showing habitat types and distribution.

II. MATERIALS AND METHODS

A. Study Area

The study was carried out in Amurum Forest Reserve (9°53'N, 8°59'E). It is located 15km, northeast of Jos, Plateau State, North-Central Nigeria. The reserve covers an area of about 300 hectares with an altitude of 1280 a.s.l. [10] and is characterized by various habitat types, namely patches of gallery forest, scrub savannah, grassland and rocky outcrops. The gallery forest is comprised of some fringing forests occurring around seasonal creeks and streams. The scrubland consists of a mixture of grasses, shrubs and small trees, while the rocky outcrops are widely distributed in the reserve having a few plant communities at various heights made up of trees and small woody plants.

B. Bat Capture Techniques

Fieldwork was carried out between May and June, 2014 in Amurum Forest Reserve and the surrounding area. Two representative sites for bat surveys were selected from each of the four habitat types in the reserve and one from the surrounding area: (i) gallery forest, (ii) savannah, (iii) rocky outcrop, (iv) farmland. Two trapping stations of at least 100 m apart were established in each site. In each site, bats were captured using mist nets with a 36-mm mesh of 50-denier nylon (18 m long x 2 m high and 12 m long x 2 m high) and canopy mist net set up. Canopy net was set up using ropes and karabiners between adjacent tall trees, such that the nets fixed with the rope network could be raised to as high as 9m. In all, 54 independent capture stations were established with mist nets representing, at least, 1800 m^2 of mist-net collecting surface operational for a total of 145 hours. Nets were opened between 19:00 and 05:00 h at each site. Due to a limited number of nets available, sampling was systematic among sites.

Bats captured were identified to species level with the aid of The Mammals of Nigeria [11], The Bats of West Africa [12], and The Mammals of Africa [13]. To avoid re-sampling of individuals, markings [14] were made on each individual using permanent marker on the neck region of the bat before release. The netting site and the microhabitat type were recorded for each bat captured.

III. STATISTICAL ANALYSIS

All statistical computing were done using the statistical software R version 3.1.0 [15] and Microsoft Excel spreadsheets for the estimation of species richness, diversity, dominance (Simpson's index), and shared species. Samples species-effort curve was plotted for the survey to determine if survey effort was sufficient

Bat species Alpha-diversity was calculated for the four habitat types and sites using Shannon-Weiner diversity index, H

$$H = -\sum_{i=1}^{S} P_i \ln P_i \quad (1)$$

Where Pi is the proportion of individual species, and S is the total number of bat species captured (Number caught in the net).

Pielou's or Species evenness refers to how close in number each species in an environment are. This is a measure of the relative abundance of the different species making up the

richness of Amurum Forest Reserve. Mathematically, it is defined as a diversity index, a measure of biodiversity which quantifies how equal the community is numerically.

Here we calculated Pielou's evenness J′ [16], which is expressed by the Shannon information scaled by the maximum information, to measure species evenness for each habitat type:

$$J' = \frac{H'}{In(S)} \quad (2)$$

Where H′ represents the observed value of Shannon-Weiner index, and S is the total number of species observed. The Pielou's evenness J′ as the evenness index was chosen based on the reason that it is the most widely used in ecology. Another reason is that it is has been demonstrated in a study on a tropical forest that species richness predicted by species-abundance models increases with increasing evenness measured by J′ [17]. The value of J′ ranges from 0 to 1, with larger values representing more even distributions in abundance among species. Reference [18] had shown that Pielou's J′ is a good measure of 'relative evenness' and that relative evenness is the correct measure given the non-independence of richness and evenness.

Species richness was calculated based on the number of different species represented in each habitat types. This was simply a count of species without taking into account the abundances of the species or their relative abundance distributions.

Similarity in species richness between pairs of habitat types was compared using the Jaccard index (SCj). The formula is:

$$SC_j = [c/(A+B-c)] \times 100 \quad (3)$$

Where A and B are the richness of two different habitat types, and c is the number of species found in both habitat types.

IV. Results

Three hundred and twenty-one bats comprising 9 species were recorded in 19 trap nights covering a total trap-length of 2088 m in four habitat types within the Amurum Forest Reserve and on adjacent farms. Of the 321 captures, 46% were captured in the savannah habitat (147), 31% in gallery forest (99), 12% rocky outcrop (37), and 12% in farmland (12). The species captured in the survey and the habitats of their occurrence are presented in Table 1.

Completeness of the survey, in terms of the proportion of bat species captured, was estimated using a species-effort curve for the entire survey across the habitats. The species effort curve for the bat species sampled (Figure 2) during this survey showed a sharp climb in the number of species detected until about 88 hours were sampled then it became less likely that more species would be found; indicating that the total number of hours invested in survey have given a reliable picture of the bat species composition and diversity.

Shannon-Weiner diversity index (H') revealed highest species diversity in the savannah habitat, followed by farmland, rocky outcrop and gallery forest. Species richness was highest in savannah followed by farmland, gallery forest and rocky outcrop. Pielou's index revealed even distribution of abundances amongst bat species in the farmland, followed by rocky outcrop and savannah on equal scale relative to the gallery forest (see Table 2).

Jaccard index (SCj) for comparing species richness between habitat pairs revealed that the farmland was 57% similar to rocky outcrop, and 70% similar to savannah. Gallery forest was 80% similar to rocky outcrop, 50% similar to savannah, while the rocky outcrop was found to be 40% similar to the savannah habitat.

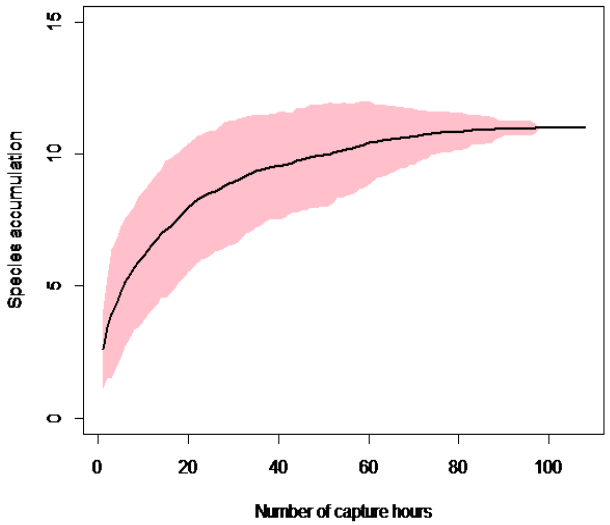

Figure 2. Bat species capture effort curve. The shaded region represents the upper and lower ranges of 95% confidence intervals

TABLE I. BAT SPECIES CAPTURED AND THEIR HABITATS OF OCCURRENCE.

Species	Farmland	Gallery Forest	Rocky Outcrop	Savannah	Total
Eidolon helvum	√	×	×	√	2
Epomophorus anurus	×	×	×	√	1
Epomophorus gambianus	√	√	√	√	4
Epomophorus wahlbergi	√	√	×	√	3
Micropteropus pusillus	√	√	√	√	4
Myonycteris species	×	×	×	√	1
Nanonycteris veldkampi	√	√	√	√	4
Rhinolophus species	√	×	×	√	2
Rousettus aegyptiacus	√	√	√	√	4
Unidentified species	×	×	×	√	1
Number of species/habitat	7	5	4	10	

√=presence of the species, ×=absence of the species.

Of the species captured Microteropus pusillus was most abundant and occurred across all the habitat types (Table 3). Bat abundance was significantly different across habitat types ($\chi 2=101.82$, df = 3, $p < 0.00001$); being highest in the savannah relative to other habitat types and least in the rocky outcrop (Figure 3). Gallery forest and savannah habitats were significantly different from the farmland (Table 4), while the rocky outcrop was not significantly different from the farmland (Table 4, Figure 3).

TABLE II. DIVERSITY INDEXES FOR BAT SPECIES IN AMURUM FOREST RESERVE

Habitats	Diversity (H')	Richness	Evenness (J')
Farmland	1.3	7	0.7
Gallery forest	0.7	5	0.4
Rocky outcrop	0.8	4	0.6
Savannah	1.4	10	0.6

I. DISCUSSION

Fifty-four independent capture stations were established with mist nets representing, at least, 1800 m^2 of mist-net collecting surface operational for a total of 145 hours. Of the 321 capture, savannah had the highest followed rocky outcrop and least in the farmland. 9 species were captured and 3 unidentified species (Table 1). Of the 9 species 8 were fruit bats (Pteropodidae), while only 1 insectivorous bat (Rhinolophidae) was captured throughout the survey. All the 9 species were encountered in the savannah habitat and the unidentified species, 7 in the farmland and least in the rocky outcrop indicating highest species richness in the savannah (Table 3, Figure 3).

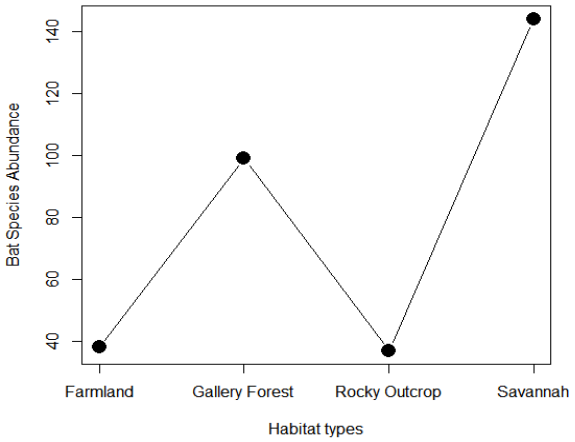

Figure 3. Bat species abundance in the various habitat types

TABLE III. NUMBER OF BAT SPECIES CAPTURED PER HABITAT

Species	Farmland	Gallery Forest	Rocky Outcrop	Savannah	Total per species
Eidolon helvum	4			13	17
Epomophorus anurus				2	2
Epomophorus gambianus	1	2	2	11	16
Epomophorus species				1	1
Epomophorus wahlbergi	2	1		2	5
Micropteropus pusillus	24	77	28	81	210
Myonycteris species				4	4
Nanonycteris species			1		1
Nanonycteris veldkampi	4	1	1	1	7
Rhinolophus alcyone	1				1
Rhinolophus fumigatus				1	1
Rousettus egyptiacus	2	18	5	28	53
Unknown				3	3
Total per habitat	38	99	37	147	321

TABLE IV. STATISTICAL SUMMARY TABLE OF VARIATION IN BAT SPECIES ABUNDANCE ACROSS HABITATS

	Estimate	Std. Error	z value	Pr(>|z|)
Farmland(Intercept)	38	6.164	6.164	<0.00001
Habitat(Gallery Forest)	61	11.705	5.212	<0.00001
Habitat(Rocky Outcrop)	-1	8.66	-0.115	0.908
Habitat(Savannah)	106	13.491	7.857	<0.00001

This could be attributed to the observed abundance of fruit plants and roosting sites in the savannah relative to other habitat types. Species diversity was highest in the savannah and least in the gallery forest (Table 2). This is against the report of Shannon diversity being highest in gallery forests and lowest in savannah plots by [19].

Species evenness was highest in the farmland and least in the gallery forest (Table 2). This indicates that the bat species captured in the farmland are numerically related in terms of the number of individuals captured per species. This relates to the reduced heterogeneity of the farmland habitat. Species capable of surviving in this habitat may be closely related in abundance with reduced competition. The disproportionate abundance of *M. pusillus* relative to other species in the gallery forest may account for evenness being the least compared to other habitat types.

There was high level of similarity in bat species composition between farmland and savannah and between gallery forest and rocky outcrop as revealed by Jaccard index. This could be due to relatedness in roost site availability and fruit plant species richness and abundance. The farmland habitat was observed to be surrounded and separated by patches of savannah habitats, as this may increase the level of species interaction across the two habitat types. The similarity between gallery forest and rocky outcrop in terms of species composition may be due to choice of roosting site and foraging site. Some of the individuals that roost in the gallery forest may prefer to forage in the rocky outcrop habitats. Differences in altitude and fruit plant availability may account for the low similarity between rocky outcrop and savannah habitat types.

Species accumulation against number of capture hours curve for the entire survey showed adequacy of survey effort (Figure 2). This applies strictly to fruit bat species, as species diversity and abundance for insectivorous bats cannot be accounted for by this survey. This is due to limited capture of insectivorous bat species.

Microteropus pusillus was the most abundant species (Figure 4, Table 1) which occurred in the four habitat types, followed by *Rousettus aegytiacus* and *Eidelon helvum* while *Rhinolophus* species were the least abundant (Table 3). The high abundance of *M. pussillus* can be attributed to its ability to make use of the different habitats without exception. Reference [19] also recorded a disproportionately high dominance of *Micropteropus pusillus* from their survey. The present survey does not provide enough data on the abundance of insectivorous bats as we only had 2 captures of them.

II. CONCLUSION

The savannah habitat has the potential to host a great degree of fruit eating bats relative to other habitat types due to its associated higher ecological services, which hosts a variety

of resources required by fruit eating bats in terms of roosting and variety of fruit plant species. The preference of one habitat type over another by some individuals of the same species necessitates the protection of the four habitat types as they play significant complementary role in improving bat species assemblages in Amurum. Low bat abundance recorded in the farmland and the rocky outcrop habitats is an indication of high level of habitat simplification and disturbance through various agricultural practices and reduced habitat suitability for the fruit eating bats in the habitat types respectively.

Different bat species do not respond equally to habitat modification or disturbance, resulting in the more generalist species (e.g. *M. pusillus*) colonizing all the habitat types. Specialized species are likely to be more affected by environmental perturbations, especially those caused by anthropogenic events.

Bats comprise an extremely interesting and highly beneficial component of our fauna. Therefore, we should make concise effort to understand and appreciate them rather than fear and persecute them. As observed in many wild animals, bats sometimes pose public health threats and may become nuisances by residing where they are not wanted. However, their immense benefit as the only major predator of night-flying insects greatly outweighs their negative aspects.

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